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Analysis of water quality parameters and ecosystem services of Nzovwe stream

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ABSTRACT
This paper presents analyzed physico-chemical parameters and assessed ecosystem services of Nzovwe stream. Physico-chemical parameters were analyzed using methods and procedures as prescribed by American Public Health Association and Tanzania Bureau of Standards. Whereas, ecosystem services were assessed qualitatively using households survey questionnaires. In average the water sample from Nzovwe stream had the following measurement; pH was 8.14(±07SD), Temperature 24.7(±0.2SD)^{0}C, Turbidity 320(±20SD)NTU, Total alkalinity 202(±2SD)mg/L, Total hardness 58(±8SD)mg/L, Electrical conductivity 540(±20SD)µs/cm, Total suspended solids 314.027(±73.19SD)mg/L and Total dissolved solids 361.8(±13.4SD)mg/L. Field observations revealed that the stream is in danger of being polluted due to human activities (i.e. washing clothes and bathing, cultivation or gardening, irrigations) and dumping of wastes from households. Physico-chemical parameters showed no or little evidence of a stream being polluted because almost all parameters were within permissible range of Tanzania Bureau of standards (TBS). About 90% of interviewed households said that Nzovwe stream supply them with provisioning services (fresh water for drinking, washing, bathing, or sanitation purposes and other domestic uses); 3% said that they extract building materials (soil and pebbles); 5% specified that they use stream water for irrigation of crops (banana trees, maize) and gardens (vegetables); while 2% obtain pastures to feed livestock. This study recommends that future studies must include biological parameters instead of using only physico-chemical parameters to assess the quality of water in Nzovwe stream. Moreover, local authority must ensure that the stream is well protected by establishing stream management committees which will incorporate individuals from households adjacent the Nzovwe stream.

Key words: Water quality, Water pollution, Physico-chemical, Parameters, Ecosystem services, Nzovwe stream

INTRODUCTION
In Developing countries, scarcity and water pollution constitute a primary challenge for sustainable water resources management [1]. Despite the World Health Organization's guidelines (WHO) [2] for drinking water quality, water pollution in various sources has been continuously increasing in most countries [1, 3, 4]. Thus ensuring water quality must be an issue of scientific and public concern. Scientists and researchers have identified several factors that threaten water quality. These include but not limited to habitat destruction, invasive species, pollution and human overpopulation [5, 6]. Several studies also have shown that many fresh water bodies are continuously being disturbed and polluted due to human activities which influence changes in hydrologic regime, water quality and biodiversity of water bodies [5, 7].

Pollution of many small rivers or streams in developing countries has been increasing as result of poor management and increase in human population. This is because, when the population increases, people demands more water for economic activities such as agriculture and for domestic uses. However, some of their activities affect the ecosystem health as well as the flora and fauna of these water bodies [8, 9]. Moreover, polluted water affects human, animals and plants due to change in the physico-chemical and biological characteristics of water [8]. High levels of pollutants mainly organic matter in water bodies may cause an increase in biological oxygen demand, chemical oxygen demand, total dissolved solids, total suspended solids and fecal coliform [10, 11]. These make water unsuitable for drinking, irrigation or any other use.

Due to increase of water pollution in smallest unmanaged rivers and streams either deliberately or accidentally, this study wanted to assess water quality of Nzovwe stream using physico-chemical parameters. The stream receives many pollutants from neighbouring households and hence reducing the quality of water. Contaminated water can affect the health of ecosystem and organisms (people, animals and plants) living in or using that particular water. Water quality refers to the standard chemical, physical, and biological characteristics of water which measure the condition of water relative to the requirements of one or more biotic species and or to any human need [12].

It is imperative to analyse physico-chemical parameters in order to get precise knowledge about the water quality and compare the study results with standard values. Patil *et al.*, [13] underline that it is important to check the quality of drinking water regularly at time interval, because human population is usually harmed from waterborne diseases due to use of contaminated drinking water. Thus, improving water quality can prevent water associated diseases [12, 13]. It is also important to understand the values or concentration of different physico-chemical parameters including but not limited to dissolved oxygen, pH, hardness, alkalinity, temperature, acidity, sulphate, chloride, colour [14, 15] and heavy metals (Pb, Cr, Fe, Hg etc) because of their special concern as they produce a long-lasting poison in aquatic animals [16, 17]. However this current study analysed few physico-chemical parameters namely pH, temperature, turbidity, total alkalinity, total hardness, electrical conductivity, total suspended solids and total dissolved solids) and none of the heavy metals were assessed.

The Tanzanian Bureau of Standards (TBS) [18] is the principal agency in Tanzania governing the quality and standards with respect to attributes and parameters

which are of direct relevance and importance to the human population at large. TBS has entrusted upon itself the responsibility of setting and maintaining drinking water quality standards. The standards prescribed by TBS (Table 1) have been used in this research work in order to assess the Nzovwe stream water quality. This is largely because the sites (ST1, ST2 and ST3) from which water was sampled are directly used for human consumption. Apart of using TBS standards, also this research used the standards for drinking water quality of World Health Organization (WHO) (Table 1) [2].

The objective of this paper is to assess and analyse the water quality of the Nzovwe stream using physico-chemical parameters; to assess ecosystem services and predict the possible danger to aquatic life in Nzovwe stream and recommend necessary steps to be taken into account by the local communities and authority to manage the Nzovwe stream, its ecosystem and avoid or reduce pollutions.

MATERIALS AND METHODS

The description of the study area

The Nzovwe stream (8° 53′24″S 33 ° 25′48″E) in the Nzovwe ward is located in Mbeya municipal of the Mbeya Region (08°54′S 33°27′E) in Tanzania [19, 20]. It is one of the smallest streams in Mbeya city which supplies water for domestic uses and irrigations. The stream is continuously been polluted by domestic wastes and agriculture activities. These activities threaten the health of local people and environment. Present study aimed to address the quality of water of this stream and its ecosystem services. The stream also receives water from many small tributaries coming from different neighbouring areas and usually it overflows during rain seasons. The area receives moderate rainfall from December to April approximately 1400mm-1600mm per year, the remaining months area does not receive rainfall. The Nzovwe stream was selected for this study because it receives a lot of domestic wastes from human activities. According to the 2012 census in Tanzania, the Nzovwe ward has a total population of 22,898, among this male are 10,823 and female 12,075; while the average household size and sex ratio is 4.5 and 90 respectively [21].

Research methodology

Water samples for analysis were collected during June-August 2015. Sampling sites were identified with an objective of obtaining representative water samples from the study area. The samples were collected from three locations identified as polluted site (ST1), least polluted site (ST2) and unpolluted site (ST3). These locations were identified based on the following criteria: ST1 was observed having a lot of human activities, degraded sites, presence of domestic animals or their signs and domestic wastes; ST2 had only human activities and no domestic animals or their signs, no degraded sites and domestic wastes; and ST3 had none of the mentioned characteristics above. Five samples of water were collected from each location making a total of 15 samples. The samples were collected in clean polythene bottles that have been prewashed with 10% nitric acid and thoroughly cleaned with deionized water. Water samples were analysed in the biology and chemistry laboratory, at Mbeya University of Science and Technology (MUST).

Water were analysed for the following physico-chemical parameters; temperature, pH, alkalinity, electrical conductivity (EC), total suspended solids (TSS), total dissolved solids (TDS), hardness and turbidity. Total suspended solids (TSS) and turbidity samples were held in the dark at 4^oC. Nephelometer, thermometer, electrical conductivity (EC) meter and pH meter was used to measure water turbidity, temperature, EC and pH of the water samples in situ respectively.

Total suspended solids (TSS) are regarded as type of pollution because their high concentration in water is capable to affect growth and reproduction rates of aquatic flora and fauna, and reduce water quality for domestic use [22]. The TSS consist of clay, silt, and fine particles of organic and inorganic matter [14, 23]. For analysis of TSS, a known quantity of sample was filtered through the pre weighed filter papers. The filters were first prepared by soaking them in distilled water and then dried at 103^0C, and weighed in order obtain their initial weights (B). The dried weighed filters were placed onto a filtering flask. The water sample was shaken and poured through the filter. The volume or amount of the filtered water was recorded (C). The filter was removed and dried at 103 to 105^0C, and allowed to cool at room temperature, and weighed to obtained the final or end weights (A). The TSS was calculated by using the equation below as described by Adnan *et al*., [14] and Anon [24].

$$TSS\ (mg/L) = (A-B) * 1000]/ C \text{ in } mL$$

Where

A = final or end weight of the filter (weight of filter + dried residue) mg

B = initial weight of the filter, mg

C = volume or amount of water filtered, mL

Total dissolved solids (TDS) are the measure of total inorganic salts and other substances that are dissolved in water [15, 25, 26]. For TDS analysis, collected water sample was kept at 25^0 C at the time of analysis. The ability of collected water sample to conduct electricity was measured using electrical conductivity meter in the SI unit μS (micro-Siemens). The TDS was determined by using electrical conductivity (EC) method and obtained data were entered into the formula below to calculate TDS as describe in Adnan Amin *et al.*, [14].

$$TDS\ (mg/L) = EC\mu s/cm * 0.67$$

Other physico-chemical parameters were analysed by following the procedures and methods as elucidated in WHO [2], TBS [18] and American Public Health Association [27] guidelines.

Household survey questionnaires

About twenty five (n=25) households were surveyed during the study. To avoid repeating information, only one individual (above 20 years of age) per household was questioned. The aim of this survey was to understand from households the ecosystem services supplied by or benefits they obtain from Nzovwe stream. Household sampling techniques used in this study were similar to that described in Ojija [19], Silayo *et al*., [28], and Dahdouh-Guebas *et al*., [29].

RESULTS

The study shows that physico-chemical parameters of water sample from Nzovwe stream (Table 2) are within permissible range of Tanzania Bureau of Standards (TBS) and World Health Organization (WHO) (Table 1). Physico-chemical parameters had the following mean; pH was 8.14(±07SD), temperature 24.7(±0.2SD)^{0}C, turbidity 320(±20SD)NTU, total alkalinity 202(±2SD)mg/L, total hardness 58(±8SD)mg/L, electrical conductivity 540(±20SD)μs/cm, total suspended solids 314.027(±73.19SD)mg/L and total dissolved solids 361.8(±13.4SD)mg/L (Table 1). Moreover, there was no difference in the average values of physico-chemical parameters between sampled site (STI, ST2 and ST3) (Fig. 2).

Field observations revealed that Nzovwe stream is in danger of being polluted due to many human activities that are sources of pollutants, for example, washing of clothes, bathing, dumping wastes in the stream, irrigation, and cultivation near the stream, extraction of sands and pebbles from the stream (Fig. 3). Using household survey questionnaires, households were asked to mention and explain ecosystem services supplied by or benefits they obtain from Nzovwe stream. About 90% of interviewed households said that they depend on Nzovwe stream mainly for provisioning services such as fresh water supply for drinking, washing, bathing, or sanitation purposes and other domestic uses; 3% said that the stream supply them with building materials such as sands and pebbles; 5% explained that they use water from the stream for irrigation of crops (banana trees, maize) and vegetables; whereas 2% said that they harvest grasses from the stream ecosystem to feed their livestock (Fig. 4 and 5).

DISCUSSION

Physico-chemical parameters

Most of the Physico-chemical parameters showed no or little evidence of pollution in Nzovwe stream because they were within permissible limit of Tanzanian drinking water quality standards according to TBS [21]. Also, the water from Nzovwe stream can be classified as soft water since its hardness is 58mg/L. This is according to the United States Geological Survey classification of water hardness, whereby soft water has hardness between 0-60 mg/L [30]. The total hardness levels are not supposed to exceed 500 mg/L according to WHO standards and 600 mg/L TBS standards (Table 1). The Nzovwe stream water hardness was within the permissible range (500-600) mg/L of TBS and 500mg/L of WHO (Table 1). However it is vital to know that high hardness values can cause diarrhea, kidney stones, and irritation of intestinal tract [31]. Furthermore, the mean values of physico-chemical parameters showed no variations between sampling sites (Figure 2).

Adnan *et al*., [14] described that a pH is important limiting chemical factor for aquatic organisms, so any changes in pH can change the characteristics of water chemistry. If the water in a stream is too acidic or basic may interfere with the biochemical reactions of aquatic organisms' by impairing or killing the stream organisms [32, 33]. Moreover, such water becomes unsafe for domestic use. Additionally, it has been reported by Adnan *et al.*, [14] and Ahmed and Tanko [34] that optimum pH of irrigation water ranges from 6.5 to 8.5, while the permissible limit is 9. Since the pH of water sample from Nzovwe stream is within permissible limit of 6.5-9.2 and 6.5-8.5 of Tanzanian standards (TBS) and WHO respectively (Table 1 and 2). Therefore it can be concluded that this can be used for several domestic purposes. Similarly, the water is good for aquatic organisms.

The mean value of turbidity of Nzovwe stream was 320 NTU (Nephelometric Turbidity Unit) (Table 2). This result revealed that water was highly turbid because it is above the permissible concentration of TBS (Table 1). Consequently the water may not be safe for drinking, however can be used for other purposes [35]. High turbidity may affect the quality of water in the stream and surrounding ecosystem [36] and this can indicate an unhealthy or poor-functioning ecosystem [37]. Also, the upper levels of turbidity exert several harms for stream systems, for instance, turbidity blocks out the light needed by submerged aquatic vegetation [10, 22]; and may be associated with disease causing bacteria's [13]. Turbidity in Nzovwe stream may be caused by soil runoff from cultivated areas as the result of irrigations of nearby gardens and cultivated lands.

Like a pH, water temperature controls aquatic life [23]. Usually it controls metabolic rates, reproductive activities and life cycles of aquatic organisms. Any increase, or decrease or widely fluctuation in a stream temperature can slow down metabolic activities, speed up, malfunction, or stop altogether [32-34]. It is known that concentration of dissolved oxygen in water body is affected by temperature, and it dissolves more easily in cold water [23, 38]. In this study, it was found that the mean temperature of Nzovwe stream water is 24.7^{0}C

(Table 2). Though this temperature is within allowable range of TBS (20-25^{0}C) (Table 1) but it is approaching the limit. This may be influenced by the sun's heat as the temperature was measured during summer in afternoon hours, or may be due to other undetermined parameters such as heavy metals and chemicals in the stream.

The TSS and TDS were 314.027mg/L and 361.8mg/L respectively (Table 2). The values of TSS may be due to re-suspension of sand and clay particles due to extraction of sand and pebbles from Nzovwe stream, which are collected as building materials. TSS in the stream can also be due to decaying plant matter [39] due to agricultural activities which dominate almost the entire length of the stream. TDS in the Nzovwe stream could be caused by presence of dissolved salts [26]. The effects of high concentration of TDS include but not limited to undesirable water taste, gastro-intestinal irritation, corrosion or incrustation [40]. The TDS value is not exceeding the maximum concentration of WHO (Table 1) and TSS is within the permissible limit of TBS (Table 1). Since a good drinking water need less of these solids, therefore, due to high concentration of TSS and TDS the Nzovwe stream water is not safe enough for drinking [41], nonetheless can be used for other domestic uses.

The mean value of electrical conductivity (EC) in Nzovwe stream was 540µs/cm (Table 2). The EC value may be caused by different dissolved solids [40-42]. Usually higher EC in water is due to its high ionic concentration. And the sources of dissolved solids in Nzovwe stream are likely to be from domestic wastes and agricultural activities. Like other physico-chemical parameters, high value of EC may have effect on living organisms. For instance, the high conductivity increases corrosive nature of water and consequently become unsuitable for drinking; however it may save for other uses [42]. Yet, the EC of water from Nzovwe stream is within permissible limit of TBS and WHO (Table 1)

The mean value of alkalinity was 202mg/L (Table 2). This may be due to the activities of bathers and washers (Figure 3). Therefore the use of soapy may be responsible for this [43]. This may also be contributed by dissolved gases such as CO_2 [44]. Moreover, the alkalinity value is above the Tanzanian standards water quality limit (100-200)mg/L (Table 1). For drinking the water may not be good, nevertheless can be used for other purposes. This is because the high concentration of alkalinity can cause, for instance, the boiled rice turns yellowish [40, 13].

Ecosystem services

Like other fresh and marine water bodies do supply ecosystem services to adjacent households [45-47], it was found that Nzovwe stream also supplies some important ecosystem services to neighbouring households. For example, 90% of interviewed households said that the stream supplies them with provisioning services such as fresh water for drinking, washing, bathing, or sanitation purposes and other domestic uses (Fig. 4 and 5). The remaining percent of households specified that the stream supply them with building materials such as soil and pebbles which are solid to obtain income. Some use the stream water for irrigation of crops such as banana trees, beans, and maize, as well as vegetables, whereas others harvest grasses to feed livestock (Fig. 4 and 5). Therefore the Nzovwe stream is important as it supplies several ecosystem services to nearby households.

CONCLUSION AND RECOMMENDATION

In this study it was found that water bodies with poor management are under high risk of being polluted. This can jeopardize the health and life of people using that water for domestic use because such water may be contaminated. The only way to ensure safety of people using the water from such water bodies is to assess its quality by using physico-chemical parameters. However, to be more certain with water quality, biological parameters such macroinvertebrates (caddisflies, mayflies, stoneflies etc.) and microinvertebrates (i.e. *E.coli*) should be also assessed. This is because using only physico-chemical parameters may or may not provide enough information about the status of water quality. Water quality analysis should be done regularly at time interval. Furthermore, the need to assess water quality is not only for health of human being but also for aquatic fauna and flora. This is because health ecosystem of water bodies supplies many ecosystem services to neighbouring households. Therefore this study recommends that following studies must use both physico-chemical and biological parameters to assess the water quality status of Nzovwe stream. Moreover, local authority must ensure that the stream is well protected by establishing stream management committees which will incorporate individuals from households adjacent the Nzovwe stream.

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Table 1: Standards for drinking water quality used in this research

Parameters	TBS, Tanzanian standards	World Health Organization (WHO, 2008)
	Permissible range/concentration	Maximum allowable concentration
Turbidity	5-25 mg/L	5 NTU
pH	6.5-9.2 mg/L	6.5 - 8.5
Electrical conductivity	2000 µs/cm	1400 µs/cm
Total hardness	500-600 mg/L	500 mg/L
Total alkalinity	100-200 mg/L	600 mg/L
Temperature	20-35^{0}C	-
TSS	100 mg/L	-
TDS	-	500 mg/L

Table 2: Physical-chemical characteristics of Nzovwe stream water

	Measured parameters							
Site	**T 0C**	**pH**	**Turbidity NTU**	**Total alkalinity mg/L**	**Total hardness mg/L**	**[a]EC µs/cm**	**[b]TSS mg/L**	**[c]TDS mg/L**
ST1	24.9	8.9	300	200	50	520	298.88	348.4
ST2	24.5	7.81	340	204	66	560	393.6	375.2
ST3	24.7	7.71	320	202	58	540	249.6	361.8
Total	74.1	24.42	960	606	174	1620	942.08	1085.4
Mean	24.7(±0.2)	8.14(±07)	320(±20)	202(±2)	58(±8)	540(±20)	314.027(±73.19)	361.8(±13.4)

Values are mean of 3 stations ± SD; [a]Electrical conductivity; [b]Total suspended solids; [c]Total dissolved solids

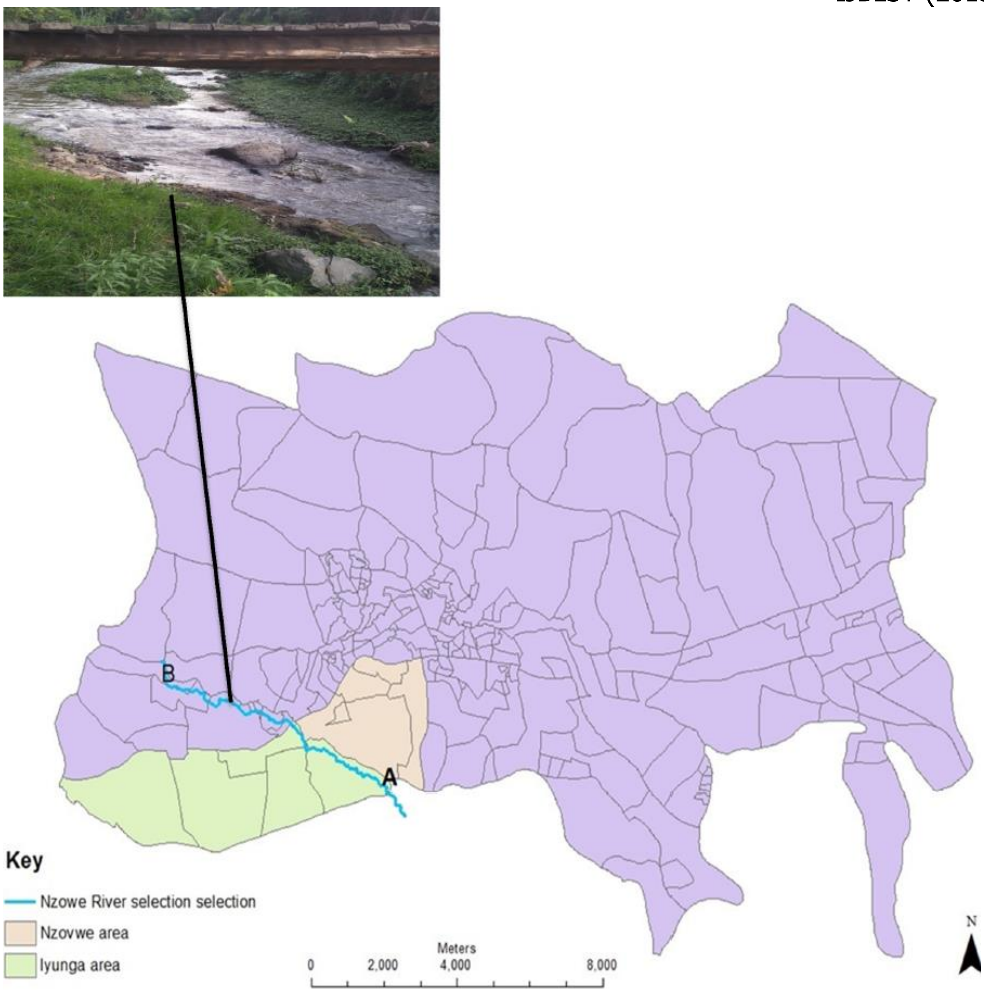

Fig.1 Map showing Nzovwe stream (A-B) in Mbeya town

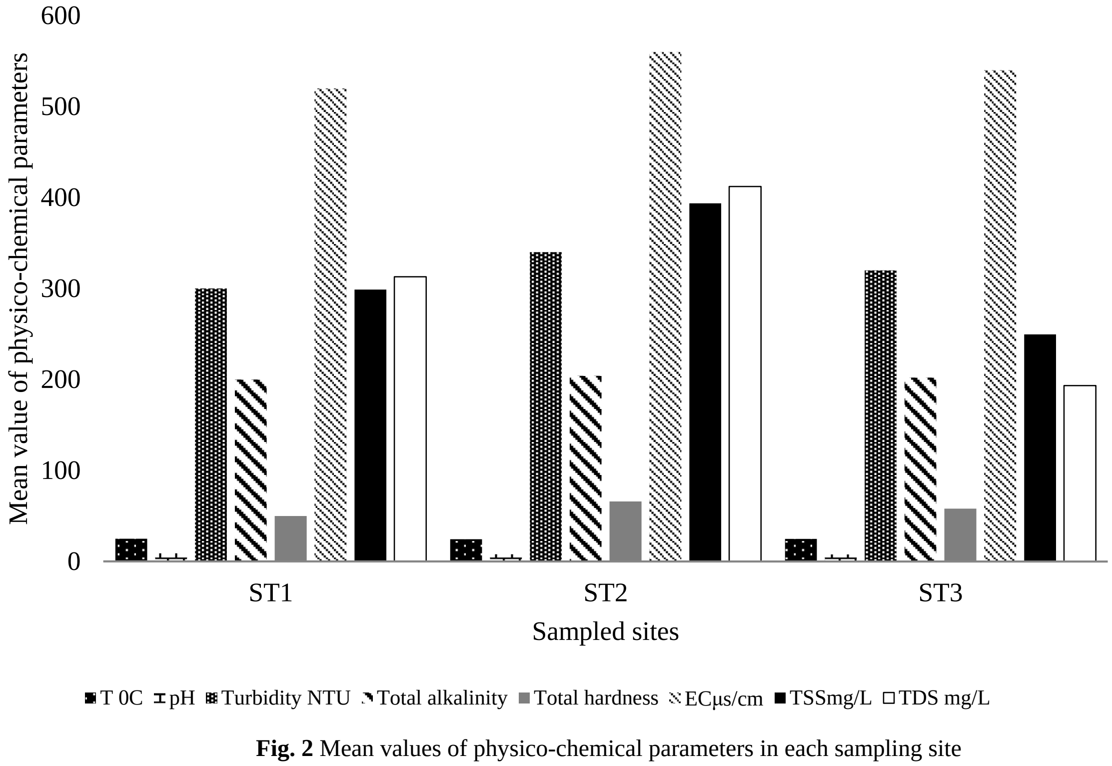

Fig. 2 Mean values of physico-chemical parameters in each sampling site

Fig. 3 Observed human deeds ((a) washing of clothes and (b) dumping of wastes) that are source of pollution in Nzovwe stream

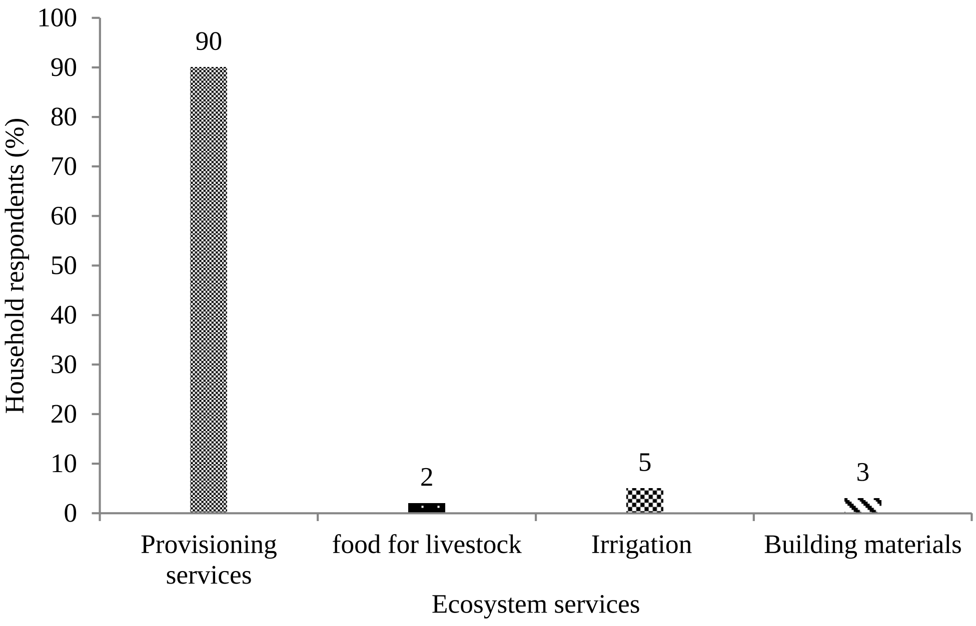

Fig. 4 Ecosystem services supplied by Nzovwe stream (based on household respondents)

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Fig. 5 Some of the ecosystem services supplied by Nzovwe stream to local residents: Provisioning services i.e. (a-b) water for irrigation, (c) washing clothes and other domestic uses; Building materials i.e. (c) pebbles and stones and (f) sand extracted from the river; (e) Tall grasses along Nzovwe river(used to feed livestock).

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